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Project Teaching*

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There is a difference between the "logical" and "psychological" treatment of any subject. Let us imagine a child so young that he has never seen a dog, and then he sees a dog for the first time. He comes away with a notion (expressed in our words) that a dog is a small white animal of about a certain size. His experience has led him to this notion of what a dog is. We know so much more that it seems wrong to call this a logical formulation; yet relative to the child such it is. The experience while he was going through with it was "psychological" in character, and the conclusion is "logical." In the "logical" then he has summed up his experience with the dog and is prepared to expect certain things of a dog the next time he should meet one.

When the child sees a dog again we will say that it is a large, black, growling dog. The child combining this experience with the preceding; now has the notion that dogs may be black or white, large or small, and kind or cross. He has had two "psychological" experiences and has made two successive "logical" formulations. The second "logical" summed in organized form the two preceding experiences. The first "logical" under the in-

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***This is not an article written by Professor Kilpatrick, but a compilation—made by permission—of notes taken by various people who have heard him speak on the subject. We recognize that the account as given is necessarily meager; we believe that it is fairly accurate. In any event, Professor Kilpatrick is not responsible for it in the same sense as if it were the product of his pen.**

fluence of the second experience gave way to and was merged in the more inclusive second "logical." As time goes on the boy gets a very complete knowledge of dogs,—a much more inclusive "logical" organization. Finally, if his interest and study of dogs continues, he may sum up the most that science has to offer about dogs. He then has a kind of nth degree "logical," which is the logical of science or logic.

In teaching we too generally take the child at the beginning stage of experience and try to give him the most complete adult formulation. We think that we will save time if we give him the adult formulation right out. This is giving the child predigested knowledge; and predigested knowledge, like predigested food, is not good for growing people. The getting must be largely the result of personal experiences; and if we attempt to give directly the results of logical formulation we fail.

Much of our school work is gone at backwards. We prepare a highly organized course, the product of the adult mind, and thrust it upon the child's immature mind and expect him to profit by it because it is so logical and correct in every respect. All the matter is classified and sub-classified. The pupil goes through this matter in the precise manner in which it is offered. This is not the true method of learning. The things we know that do us the most good were not learned in this way, but in spite of it. Mere familiarity with logical organization need not result in logical grasp or logical thinking. The contrary is even more probable.

Activity is the central notion of experience getting. Is all activity equally worth while educationally? If one person sets up a certain goal to be reached and another strives, the activity of neither party is complete. If an individual sees a thing to be done and then proceeds to do it, and tests himself as to whether he has done it, he has shown a complete activity. In the course of living a project arises to the individual. He feels definitely the need of going ahead with his project. He thinks, plans, and devises. He strives to realize his idea or project by carrying out the mediating steps devised. The result attained tests the accuracy of his thinking and doing. These several successive steps form a complete cycle of activity. It is this complete activity which is most helpful educationally. Whenever an individual starts off on a certain line, and sees for himself what he is going to do, he is working on a project. The formation of the word gives the clue. A project is something pro-jected, a pro-ject, a line of activity held before one and accepted for execution. Project teaching is teaching by means of projects which the individual thus puts before himself to be done. The aim or purpose of project teaching in science is to get the child to propose to himself things to be done in the science field, and to base the work of instruction upon such projects and the accompanying activity of execution.

In the life of a well developed person we may distinguish four stages of activity:

1. *Physical or bodily movement.* The young baby moves but does not handle things.
2. *Manipulation.* The stage in which the baby handles and fingers things, puts them into his mouth, etc.
3. *Construction and Contriving.* Things are put together or taken apart. Things are made. Thinking is done in connection with doing.
4. *Thinking.* Thinking of a higher order where the interest is the intellectual ordering of thoughts or concepts. Not all reach this stage.

The primary purpose of thinking, biologically considered, is to get out of a difficulty. The most of our thinking perhaps is of this type. We have however acquired a secondary purpose of thinking, namely to satisfy curiosity. It gives us pleasure to think. The primary purpose of hearing was for protection, to learn of approaching danger. Hearing thus is primarily to tell us what to do; but we have developed a secondary purpose of hearing, that is, to hear just because we like to hear, songs, instrumental music, etc. It is this secondary type of thinking which most concerns the scholar and scientific enquirer; tho the forms it takes are the same as of extricative thinking.

Let us consider how a child's projects grow with increasing age. The first time that a child takes a doll she merely holds it and looks at it. This is the end. She has no further desire. When she gets older she notices the dress and wishes it off. She takes off the dress. This is a more complex activity than the first; really two activities, holding the doll, and taking off the dress. She next wishes the dress back on the doll. This adds a third activity. A little later she takes off this dress and puts on another dress. She took it off purposely to put on another; which shows an added complexity. Later she takes off the dress and puts on a night dress for the doll is to go to bed. Here are steps which are almost what we call *means*. The end is to put the doll to bed. In order to do this she thinks out the means, she must take off the day dress and put on the night dress. When the child is still older she makes a dress. She may after making many dresses lose sight of the *end* (getting a dress for the doll) which she first had in her mind, and become so interested in the *means* (making the dress) that making doll dresses will become the *end*. She may then make a wardrobe for the doll. She may make a dress for herself and follow this by making a dress for somebody else. She may become a professional dressmaker, and use plans furnished by others. The plans which are now a *means* may interest her so much that she will study until she is able to originate plans. She eventually plans plans for other dressmakers. Here is an activity which began very simple and spread out to involve greater interests. The child differentiated and found interest in a small part of the whole project. Projects vary with the age of the person and differentiate as the person gets older. Among these projects will be some that are predominantly intellectual. In all these activities considered above there has been a progressively higher intellectual activity.

Suppose that a boy desires to make a boat. He may find that the boat will not stand up straight in the water. He begins to ask himself questions. He may study keels. A still older boy will go at things more scientifically and study equilibrium. Each individual experience is thus leading the boy to some new project, each involving more and more thinking if it is to prove most educative. Each again is most educative if it awakens the individual to full activity. Full activity implies and involves a true project. The project supplies an aim and directs thinking. Thinking, to be worth while, must be directed by an aim held by the person who is to do the thinking. In proportion as the person holds this aim he will be able to select data intelligently. Thinking unless it works is not worth anything. In proportion as it is possible for a person to do all of this—in that proportion he is getting educated. The aim then to be educative must be held, gripped, by the pupil, not merely by the teacher. If we assign the next ten pages the child seldom gets sufficiently interested to ask about it when he is on the street or at home. If he is working on a boat project he will prick up his ears when he hears someone mention boats. Furthermore, the child organizes his thinking more completely when he has something central as a motive and guide. The more times you as teachers can get this sort of thing going the more organization will the child get in your classes. It is the child's project that organizes his thinking. He will think more about it than about your project. When the child sees the bearing of anything it will be the better remembered. One is constantly amazed at the things a child will remember if only he be interested in them. Again a child that has worked through a project has in fact a model of action for use when he meets a similar difficulty in life. He says, "I did that, guess I can do this." He has more self-reliance. The child comes to formulation of experience through these steps. Formulation sums all preceding experience for use in the next situation.

In general science this general conception means that the boy will start out with some project which involves either as end or means the use of scientific material. If there is something in physics that is pertinent to his project he will use it. So with chemistry or botany or electricity. Each succeeding project will add more knowledge of science and should lead more surely to a use of scientific method. With these advances under proper guidance should come an increase of the more purely intellectual element. This is, the projects should become more strictly and exclusively scientific, culminating with increase of maturity in scientific specialization.

Some may feel that no place has been left for a development of scientific technique. As I recall my laboratory experience in physics much of the earlier work was learning the technique of careful measuring and weighing. Are we in advocating project teaching leaving this out of account? Precisely no. Each one learns technique best when he sees the use of the refinement. Otherwise he tends to be impatient of it. When as an adult I began to write my first book, my paragraph structure was sadly defective. Under the stress of felt need I learned in one month more of the principles of constructing paragraphs than I had in a dozen preceding years. So it is generally not only with adults but equally with children and youths.

There have been objections made to the project method. Some think that the method is too slow. The thing, however, that we most wish our children to get is an attitude toward science. One project in the realm of science devised and carried through by a boy himself is worth fifty formal laboratory exercises mapped out by the teacher. The whole attitude is changed. The boy is thence forth on the lookout to use his experience and to add to it. Again the project method is said to be too haphazard. I should say that what the boy gets in this way he has and holds; what he gets any other way is haphazard and frequently lasts only until examination time. The real difficulty of our plan is to get fruitful projects started. Here we need experimentation; meanwhile I am quite hopeful. But if a fair trial shows that it is impossible for high school boys and girls to get interested in science projects, then I say put science out of the high school. But this means a fuller knowledge of boys and girls, not merely a degree in science. I hope that the time will come when no one will be allowed to teach physics just because he has studied physics. He must know boys and girls and how their minds and spirits behave.

In the project method, then, the child begins to acquire knowledge through ordinary experience. He must organize the more important results of experience into a strategic point of view by which he will control subsequent experiences in the same region. The test of the success in science teaching by the project method is, as I see it, as follows, the more important last:

Have the pupils traversed a fair amount of the more obvious regions of science?

Have they organized some of the more strategic view points?

Have they some familiarity with available sources of information?

Are they curious about scientific matters, proposing questions, each to himself and to others?

Are they disposed to pursue their enquiries carefully (scientifically) and to carry them through to a successful conclusion?

If "yes" is the answer to these questions, the teaching has been successful.

An Experiment in Eighth Grade Science*

By LEONARD M. PATTON, Master, Edward Everett School,
Dorchester, Massachusetts.

Two years ago a Boston high school teacher of science was my neighbor in Milton. We visited together a good deal and much of our talk was about science. This man was and is an enthusiast, and, from time to time, showed me some of the notebooks of his first year high school pupils and told how he was working with them. Later I visited some of his classes to see the boys themselves. The work was so clearly, simply, and interestingly presented that it seemed to me that much of a course like that could well be given to pupils of a lower grade. We talked the matter over. He was willing to give the course a trial in our school if allowed the opportunity. The superintendent was agreeable to the plan and the principal in charge of the high school found two hours a week to give us from his program.

We took an eighth grade in our main building, a class of average ability, numbering about 40, and composed of boys and girls. Owing to conditions, we were obliged to take the two hours a week on Monday afternoons.

This two hour period may be considered objectionable and undoubtedly is not the best division of time, but we could not arrange our school schedule otherwise,—and we were surprised to find the children fresh and alert at the close of a strenuous two hours. This probably was due to the method employed.

The work continued throughout the year with a constantly growing interest and enthusiasm and many of the boys elected in June the high school from which this teacher came, principally for the purpose of continuing under him their science course.

Afterwards, in discussing the ability of the eighth grade pupils as compared with that of the pupils of the first year high school pupils, this teacher said he could see little difference, although he thought the grammar school pupils seemed a little quicker to grasp and hold the subject.

That year's work has confirmed me in the opinion that much high school science, so-called, could be given earlier than it is at the present time and that it is perfectly practicable,—if properly presented.

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*Address before the General Science Club of New England, Nov. 18, 1916.

It has been said that "He who has learned to discriminate between the essentially and relatively important has mastered the whole secret of life," but just so long as individuals differ there is bound to be a difference in opinion as to the essentially and relatively important.

This teacher spent hours over the problems; he read; he visited manufacturing plants; he talked with experts; and then—far from satisfied—he submitted his plan for a year's work.

OUTLINE OF THE COURSE GIVEN*

Project 1. A Study of Fuels used at Home.
- I. A Study of Coal (from samples).
  1. Transportation of Coal.
     - Where it comes from.
     - How shipped to Boston.
     - How unloaded and stored at the yards.
  2. A Study of Soft Coal—color, fracture, lustre, composition, uses, how it burns.
  3. A Study of Hard Coal—color, fracture, lustre, composition, uses, how it burns.
  4. Kinds of Hard Coal—Franklin, Lackawanna, Lehigh, Shamokin, etc.
  5. How to buy coal.
     - Cost per ton, quarter ton and bag.
     - When to buy coal.
     - Assurance of just weight—Study of the Weigher's Certificate.
     - Slate and water in coal.
  6. The screening of coal.

SIZE	COST PER TON	USE
PEA		
NUT		
STOVE		
EGG		
FURNACE		

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*This outline was prepared by Mr. J. Richard Lunt, of the English High School, Boston.

- II. A Study of Wood (similar to I).
- III. A Study of Charcoal (similar to I.).
- IV. A Study of Coke (similar to I.).

Project 2. My Kitchen Stove.
- I. Home study of parts and operations.
- II. Drawings to illustrate these parts.
- III. How to clean out the stove.

Project 3. How to Kindle a Fire in the Stove.
- I. Kindle a coal fire using only paper, wood and coal.
- II. Manipulation of the drafts and dampers.
- III. How the fuel kindles.
- IV. School experiment to illustrate kindling.
  - Temperatures—using a match, paper, kerosene, small splints, coal, etc.
- V. Cause of difficulties encountered.

Project 4. How the Draught Works.
- I. Kindle a fire in the stove. With a smoking splint or joss stick, trace the draught from the ash door slide to the smoke pipe.
  - Course of draught with direct draft damper open.
  - Course of draught with direct draft damper closed.
- II. What causes the draught.
  - 1. Show that air expands when heated.
  - 2. Balance two empty flasks. Heat one to show that cold air is heavier.
  - 3. Circulation apparatus. Box and two lamp chimneys.
- III. Application of the principles of circulation to the draught of the stove.

Project 5. How to Make the Fire Burn Fast.
- 1. Open ash door slide and direct draft damper.
  - Hold a smoking splint or joss stick before the ash door slide.
- 2. Observations.
- 3. Why the fire burns faster.
  - Air contains oxygen (given if necessary).
  - A study of oxygen (experiment).

Project 6. How to Check the Fire.
- I. Manipulation of slides and dampers.
- II. Observations.

III. Experiment. With a piece of wire lower a burning candle into a large jar. Cover the mouth.

Project 7. The Study of a Wood Fire.
- I. Observations of a wood fire at home.
  1. What are the yellow flames?
     Distill some wood in a test tube.
  2. What are the red coals?
  3. What are the black coals?
  4. How does the wood break up?
  5. What is ash?
  6. What is smoke?
     Smoking lamp good to show this.

Project 8. The Study of a Coal Fire.
- I. Observations of a coal fire at home.
  What are the blue flames?
  Rest similar to wood fire.

Project 9. What becomes of Fuel when it Burns?
- I. What remains in the stove after wood is burned?
- II. Weigh a small piece of wood. Shave it into pieces. Burn them. Weigh the ash. Find the per cent of ash.
- III. What happens to the rest of the wood?
  Ignite a small piece of charcoal. Suspend it in a jar of oxygen, keeping the mouth of the jar closed. Carbon disappears, fire goes out from lack of oxygen, both elements still in the jar.
- IV. What is formed in the jar?
  Pour a little lime water in the jar. Pour some into a second jar.
  What must this new gas be composed of?
- V. Application of principles.
  What becomes of coal when it burns?
  Coke? Charcoal?
  Blow the breath into a jar of clear lime water.

Project 10. How Heat Travels.
1. How does the heat from the kitchen stove travel to the opposite sides of the room.
   With a smoking splint or joss stick trace the circulation of air from the stove to the corners of the room. Explain.
   Open the broiler door. Hold the cheek near the door.

Can the heat come by convection? Joss stick. Hold a book in front of the cheek. Remove it. Cover part of the cheek with the book. Hold a piece of glass before the cheek. If possible do this experiment before the open fire place.

2. Put the end of the stove poker in the fire.
    - Feel of it from time to time.
    - Put an aluminum spoon and an iron or silver spoon of the same size into boiling water. Feel of the ends of the spoons.
    - Application of the principles of conduction to fireless cooker, refrigerator, wooden handles, woolen clothing, etc.

Project 11. How Illuminating Gas is Made.

I. Grind a few pieces of soft coal to a powder. Put a small quantity of this powder into a test tube. Bend a short glass tube at right angles. Insert the end through a cork stopper. Push the stopper into the mouth of the test tube. Heat the coal with a Bunsen burner.

Ignite the escaping gas.
Note the brown deposit (coal tar).
Break the test tube. Examine the contents.

II. Application to the manufacture of coal gas and coke.

III. Explanation of water gas manufacture.

IV. Illuminating gas sold in Boston. Coal and water gas.

Project 12. Properties of Illuminating Gas.

I. Collect a jar full of gas from the gas pipe by water displacement.

Observe the color. Odor.
Effects from breathing escaping gas.

II. Lower a burning candle into the jar.

Does the candle continue to burn?
Cover the mouth of the jar.
Does the gas burn?

III. Fill a jar about 1-5 full of water. Invert in a basin of water. Displace this water with illuminating gas. Cautiously hold a burning splint above the mouth of the jar.

Dangers from gas explosions. From gas leaks.

Project 13. Composition of Illuminating Gas.

I. Hold a porcelain dish in the yellow flame of the Bunsen burner.

What collects on the dish?

II. Bring a large battery jar quickly down over the blue flame of the Bunsen burner.
    What collects on the sides of the jar?
    How was this substance formed?
III. What three elements have you found?
IV. Products of combustion from illuminating gas.
    Repeat showing that water is given off.
    Burn a jar of illuminating gas.
    Add a little lime water.
    How was this CO_2 formed?

Project 14. How to Read a Gas Meter.
I. Construction of the gas meter.
II. The dial of a gas meter.
III. Reading practice from blackboard.
IV. Read the gas meter at home.

Project 15. The Cost of Illuminating Gas.
I. How it is sold.
II. Cost per 1000 cubic feet.
III. Number of cubic feet for one cent.
IV. Number of cubic feet for 25 cents.
V. The quarter meter.
VI. How to estimate gas bills.

Project 16. Comparative Study of the Blue and Yellow Flames.
I. Study of the blue flame.
II. Study of the yellow flame.
III. Which flame gives the more intense heat?

Cut two pieces of glass tubing 8 inches long. Support the ends at the same height. Use two Bunsen burners, one with a yellow flame, the other with a blue flame.

At the same time place both burners directly under the centers of the glass tubing, one burner under one glass tube, the other under the other glass tube.

Which tube bends first?

Why should we use the blue flame in the gas range?

Project 17. Boiling Potatoes with Illuminating Gas.

I. Use two small gas plates. Place two small kettles of the same size, one on each plate. Fill each kettle about ¾ full of water. Light the gas. When the water in both kettles begin to boil, turn down the gas flame under one kettle so that the water boils slowly, under the other kettle turn the gas flame up to its full height so that the water boils violently.

At the same time drop 3 small potatoes into one kettle and the same number into the other kettle. Try to have the potatoes as near the same size as possible.

II. Which potatoes will cook quicker?
    Examine the potatoes with a fork until they are soft.

III. Why do the potatoes cook as quickly in the kettle when the water boils slowly?
    With a thermometer take the temperature of the water in each kettle.
    In which kettle is more water evaporated?
    What becomes of the extra heat?
    Which kettle uses the more gas. (if possible estimate with a sweep hand minute observation meter the difference in cost).

IV. Application of these principles to home cooking.

Project 18. A Study of Open Gas Burners.

I. Types of open burners.
    Bray, Empire, lava tip, jumbo, aluminum tip.

II. How to use the open burner.
    Gas blowing, gas normal.

III. Cost per hour of open burners.
    Estimate with watch and the 2 cubic foot hand of the gas meter at home the cost per hour of an open burner.

Project 19. A Study of the Welsbach Burner.

I. The Junior Welsbach.
    Parts of the Junior Welsbach.

II. Set up each part separately. Ignite the gas to show the part each plays.
    a. nipple.
    b. cap.
    c. burner shaft.
    d. mantle.
    e. globe.
    f. shade.

III. Cost per hour (home estimate).

Project 20. The Kerosene Lamp.

Project 21. Planting a bacteria garden from dust.

Project 22. Planting a bacteria garden from a toothbrush.

Project 23. Planting a bacteria garden by letting a fly walk across the agar.
Project 24. A Study of Germicides.
Project 25. How Heat Affects Bacteria.
Project 26. The Dark Tenement House Problems.
Project 27. A Study of Molds.
Project 28. A Study of Yeast.

In these lessons no information came from the teacher. The boys and the girls reasoned from their own experience and observation.

No text-books were used, though the children were at liberty to consult books or persons if they wished.

Note-books were kept and carefully inspected to see that the pupils were getting the work as it was developed.

These note-books were so highly prized that it was difficult to secure one at the close of the course as an office record of the work.

The word "project" in this course meant a problem and its solution by the children.

Progress was slow at times, but we believe it was time well spent in teaching the children two very essential things; how to think and reason well.

At the end of the year we had a class of interested, wide awake, *thinking* boys and girls. All that they had learned had come from themselves, drawn out, to be sure, by skillful questioning, but their own experience and observation summed up, correlated and systematized.

The question may have arisen in your minds, "Why *this* choice of material?" The answer is: At that time, such a course for our particular district seemed advisable and practical. It may not in its entirety be adapted to another district nor our own two years in succession.

One of the first requisites of a good course of study in science is a close relation of its subject matter to the life and experience of the child; a dealing with the things around and about him; in other words his work must be hitched up largely to his environment.

This, our science teacher tried to do, and he seemed fairly successful, but at this point comes a difficulty. All teachers aren't adapted to science teaching; I will go farther and say that but a comparatively few can teach this subject satisfactorily.

No matter how excellent the course, or method,—in the last analysis—real success depends upon the personality of the teacher. Given the best course of study in the world and an approved method of presentation, unless the teacher is sympathetic, open-minded, willing, enthusiastic, progressive, her work will amount to little. I am convinced that before we get good results in science we must have a trained corps of science teachers, with the work properly outlined and systematically supervised.

The great trouble with our science teaching is not primarily the course, nor the method, but the lack of this trained corps of able teachers. We have a good course of study for the Boston Elementary Schools, prepared by a capable committee of men and women, but in general it is slighted and neglected all through the city, not purposely nor wilfully perhaps, but because it requires thought and preparation in foreign fields; it requires study; it is a disturbing thing because it is always so different; unexpected questions are continually coming up; it opens so many windows in the child's mind that the teacher is herself bewildered.

An upper grade teacher came to me recently, and said, "My children are driving me wild; they come to me about everything and I don't seem to know anything." That is what so many teachers dread in this science work. It embraces so much, requires so much thought and preparation, is always so new, and exposes so much of ignorance that they hesitate to enter into the conflict. As they grow older they will learn it is no disgrace not to know all things.

What can we do about it? Is there a remedy?

The following suggestions are offered in the hope that some of them may be worthy your consideration.

1. Wherever departmental teaching is feasible, have some one teacher take over the science work. It is necessary, of course, to select wisely this teacher, especially when the course is being introduced.

2. To insure success, the head of the school system must be in sympathy with the movement. In a large city system like Boston not only the head but the co-workers all along the line, must be in sympathy. In the average town the co-operation of superintendent and principals is enough. In the rural sections, where districts have not been consolidated, the problem is difficult to

solve, although the need here is greater, probably, than anywhere else.

3. Some definite financial support must be given for equipment. In the eighth grade the apparatus is simple but a small fund should be available.

4. Opportunity should be given for field work. The kind of work will vary with the opportunity, but the right teacher may be depended upon to do her part if she has liberty of action.

5. Talks and lectures by science teachers of standing and experience to groups interested in the subject, will often bear fruit, bringing many into sympathy with science teaching if not into the science teaching group.

6. There should be more science teacher training in the normal schools and colleges so that when the demand comes there will be well prepared teachers to take up the work.

7. In cities and towns, and in compact districts, there should be a Permanent Council of Local Teachers who are interested in science, whose duty shall be to prepare the course of study and supervise the work.

NOTE: For a year or more a council of Boston Normal, High, and Grammar School teachers has been working on a science course for the junior high school,—and another council is at work revising the course for the grades.

These teachers are endeavoring to eliminate all but the essentially important things from their outlines and they are having a hard time.

The work of the Junior High School Council is especially difficult, dealing, as it does, with a comparatively new phase of school organization, and attempting a three years' course for seventh, eighth and ninth grades that shall be continuous, constructive, and related science work.

But there are the problems facing all of us. Every school and district has its own work to do. No two will have the same problem or the same work, and if they did they would not go at it in the same way. We have our little bit to do here in Boston and we are doing it with pleasure. We are experimenting as you are, and talking and reading; attending lectures and meetings like this; observing, learning. Out of it all is bound to come some good and we are glad—and ought to be glad—that we have been able to do our small part.

The Selection and Arrangement of Material in a General Science Course*

Arthur C. Johnson, Jr., Englewood, N. J. High School.

To many of us within the past few years has come the need for thoughts on the subject of general science; to each has come the need for orientation with respect to the presentation of material that the pupils under our care may secure the greatest benefit with the least outlay of energy on their part and ours.

The aims for the study of general science have had various formulations. Summed up they fall under two classifications:

I. As tool material for those who later will go on in the study of the specific sciences, or some of them here grouped together.

II. As material to function in their activities beyond school life, either for those who are eliminated early from school, or who study no other science during their course.

These two aims involve somewhat of a contradiction. In the first there is a shifting of responsibility to the other courses to be pursued; our function being merely to co-ordinate and give the elements that will underlie and unite the individual sciences. Some authors go so far as to emphasize this aim. To any one who has studied the problem of elimination, or who realizes the number who graduate with a minimum of science, the second aim will appeal the stronger, and to teachers it can rightly be the only aim, for the two are not incompatible. There is the broader field and to them can come the joy of an actual accomplishment. This means and it is generally accepted that the subject matter of general science must not be differentiated as physics, chemistry, biology or what not, but must avoid these terms and become as its name implies simply science. And here is where most of the text-book authors fail. Specialists in one science usually, even though they attempt non-partisanship, their books are permeated with the attitude of their specialty, and we get the atmosphere of physics as physics, or chemistry as chemistry, even though the names be omitted. Teachers can see it and

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*Address before the Elementary Science Section of the New Jersey State Science Teachers Association, at Hackensack, Nov., 1916.

the pupils feel it. Furthermore most of the texts are permeated with the scholastic attitude and are not in themselves complete.

Let us assume that the aim is to prepare pupils for life, instead of continuing the study of science. After all, why should we shift the responsibility; it is a sign of weakness. What constitutes this preparation for life? What concrete facts have we to guide us? And what is this life for which they are to be prepared? The problem becomes what shall we give and how shall we give it? Our method historically has been to determine what we as pedagogues thought necessary, giving it as we, as adults and theorists, thought it ought to be given and with no sound theory but traditions to back us up. It is as though we worked from a program through the conditions—children—to a conceived social need and blindly thought that we met that need. We are just beginning to understand that the social need is our aim and should form our basis of orientation and that our limiting conditions are the children. It is through these that we must determine the program to meet that need. Today we are only beginning to recognize this social need and are but beginning the study of the conditions that limit us, but so far as the science program of the immediate past has been, we are almost safe in saying that it has been void of any functioning significance. This is rapidly changing. We now have several functioning branches: household physics, domestic chemistry, agricultural biology, et cetera. Go back to the early days of science teaching in the high school, or its forerunner, the academy: look over the texts in use say fifty years ago and although they were cumbersome tomes and prosy in the main, they did have a large amount of practical usable material: books almost usable today and far more satisfactory to the pupil than the texts of fifteen years ago.

We are now in a science rennaissance. The early writers recognized that there was a twofold purpose in the teaching of science, a tool side and an appreciative side and for this latter they did not hesitate to bring in play material, soft pedagogy perhaps, balancing it with the hardest kind of material development on the tool side. And they were partly right. There is and should be a play side to any subject and at the risk of being misunderstood, I will say that there is a place for soft pedagogy in the field of general science, but it means the hardest kind of pedagogy for the teacher and only play for the pupils if they gain an appreciative attitude toward science and realize that it is not so great and deep and prosy and difficult, but merely the application of every-day common sense to the phenomena of their surroundings. As one author puts it,—"Some uncommon ways of looking at common things." They have a fundamental liking for science. Have you seen a boy spend a great big fifteen cents on a copy of "Popular Mechanics" or "Popular Science Monthly"? And one of the prominent teachers in our field is even now showing us that there is teaching and teachable material in these magazines, or one of them. The text-book for general science has yet to be written and it must contain much material that will stick in the minds of the pupil readers in spite of them, because of the play material it furnishes. Some writers have approached perilously near, but all have seemed afraid to really make a point of it. Such a book will produce results beyond our present dreams.

One other point in which much error of thought exists: we work in terms of present need, of present environment. We should and must work in terms of present capacities but to satisfy a future, adult need in a world environment. Education is to train for adulthood and adult functioning as a member of society. In the selection of material we must bear these two points in mind. Choose that that will be of use to the pupil as an adult and select and arrange it so that its acquisition may be made now in immaturity. We must create a present desire through interest and this can only be done through present activities; one great part of which is play and informational amusement.

What material is within our field that the adult needs and that the child can comprehend and acquire? What are the big things within this field that every one should know, man as well as woman; in Maine as in California; poor as wealthy?

As adults, given a situation, how do they go about securing a solution of the problems of that situation? These situations do not come singly as a rule. A home builder is called upon to determine the heating plant he will install. If he builds carefully he will investigate all forms, look to the literature of all types, listen to arguments for and against each. Finally he forms a judgment and orders one form installed. He buys an automobile or a motor boat and finds that it is not simply an engine, but a multitude of mechanical devices and he sets about acquiring an operating knowledge of each. A manufacturer is called upon to install power and he compares, steam, water and electric; not its source and efficiency alone, but its utilization through the ramifications of his plant. As a member of his Town Board he is called to vote upon the installation or rejuvenation of the water system, or sewage disposal or lighting system and an enormous number of considerations enter. In every case the main problem is a complex one, made up of innumerable smaller ones.

It is the recognition of this that is bringing to us to-day a new method so-called,—the project method. This is a misnomer. It is not a method but an aim. But through it we are arriving at the threshold of a new science, a real, living, functioning, training something that makes of science a thing apart from many of the subjects of the curriculum. Already the other subjects recognize its value and are adopting or forcing it into their scheme of things.

We are falling into one misconception. We do not clearly define our method of procedure. We do not clearly see the steps involved in the logical development of science material. For general science the project must be the big inclusive thing about which information is desired or needed and includes many sub-divisions or topics. Heating is a project and the various methods of heat installation, costs, weather, conditions, fuel supply, et cetera, topics. Power is a project and the horse-treadmill, simple machines, hydrokinetics, steam boiler, Corliss engine, electric motor, et cetera, are topics. Water supply is a project and land conformation, soil stratification, rainfall, dams, filtration, water pollution and purification, all hydrostatics are topics. And again under the topic are sub-divisions, the local problems through which directly the knowledge of the other larger groupings will be acquired. With power as a project, the gas engine becomes a topic and valving, the carburetor and gearing are illustrations of problems under it. The method of handling this material is best developed by what is termed at present the project method. The situation is secured in the form of several problems to be solved individually. These collectively furnish the necessary information and technique concerning the topic and these topics in turn collectively round out our understanding and appreciation of the larger situation.

So far as actual class room teaching is concerned this all becomes a mere quibble over words. The correct class room procedure is as it has been, but the point involved concerns itself with the organization of material rather than the handling of it after it is organized. My message is to those who have this side of the situation and only to the teachers in so far as they can modify existing conditions to conform to the ideas here contained. And a little thought will show many ways in which this can be accomplished.

If the point of view that I would convey has been secured, the value of such an organization lies in the coördination of the sciences in the development of the project. There is no need to even think physics, chemistry, physiography or biology: they present themselves naturally and unostentatiously as aids in the analysis and classification of the project.

But we must get away from the idea of traditionally logical sequence. We must study a subject only when the need for its study becomes apparent in the solution of the problem in hand. Pumps are studied when it is necessary to elevate water: oxidation is studied when it is necessary to secure information as to the action of the atmosphere on substances. Our projects select themselves, but we must so arrange them that the topical problems under them form a sequence that is developmental, contiguous and continuous in character.

To be a bit more specific I believe that all the problems we have or need to consider in general science come under one of the following as projects:

The earth in its relation to man.
The atmosphere.
Water.
The human body.
Health and its preservation.
Food.
Clothing.
The home.
Heat.
Light.
Power.
Electricity.
Means of communication.
Plants in their relation to man.
Animals in their relation to man.
Recreation.
The earth's place in the universe.

All of man's activities and interests are concerned in problems under one of these major groupings. I am not yet entirely certain in my own mind as to the natural sequence in some of these; yet it is evident what the trend must be.

The child before coming to us has considered only geography of the so-called sciences and that usually in an unscientific manner. There are those who say that geography is not a fundamental subject, but nevertheless the pupil does have a certain knowledge of the world and world forms and this blends into our science of physiography. If we are to go from the known to the related unknown, our best approach is through the data of physiography working into physiology and hygiene and to the advanced sciences, advanced because foreign to the child in his school experience. Let these latter sciences enter the function whenever and wherever the need arises to clear up or amplify the work in hand and let them become increasingly predominant as the method of approach and attack becomes familiar.

To sum up, I would classify all the material to be presented in a course in general science under several great groupings that represent the interests and activities of the adult in society, making the approach as he would make it and taking up a given problem only when the need for it has arisen in the progress of making clear the larger topic. I would place first those interests that most nearly relate to the previous training and approach of the pupil. And I would not hesitate to make easy his approach to new material by the use of devices that require no deep thought in acquisition or effort in retention.

General Science Bulletin*

(*Continued from page* 46.)

MASSACHUSETTS COMMITTEE.

PSYCHOLOGICAL FACTORS AFFECTING METHOD, MATERIAL AND ORGANIZATION.

It is assumed that pupils over 12 and under 16 are possessed with large potential curiosity about natural phenomena and physical forces and their applications to industry. This interest, while

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***This is a preliminary draft and not the final report of this Committee.**

often dormant, can be easily aroused and directed when the subjects for study are presented to the child with due regard to his limitation and capacity.

Children of this age are developing initiative and self-activity along mental lines and respond quickly to suggestions by the teacher. When formal tasks are imposed, which do not appeal to the pupil's interest the effect is often to kill interest and enthusiasm.

Observation by teachers of general science warrant the conclusion that among other intellectual aspirations of pupils of this age, the desire to control and direct natural forces is strong. Others possess a keen interest in knowledge, in itself.

Children of this age also possess much unorganized, miscellaneous knowledge of nature gained from reading and experience. The kind and amount of such material differs greatly in individual children because they have had little or no formal instruction in science in the lower grades. Their ideas of nature are crude. There is much mis-information and little capacity to discriminate between reliable and merely sensational statements.

When a given unit is undertaken the teacher should ascertain at the outset what the children know or think about the subject and also what are the questions uppermost in their minds regarding the topic under consideration.

It is desirable that the pupil should become consciously or unconsciously aware of some perplexity or problem he wishes to define or identify and become eager to seek the solution by means of various crude hypotheses which he tests by observation or experience until the conclusion is reached. If the child's desire to solve a problem can be aroused then he works consciously to satisfy a personal need. This need may rise in the ordinary course of experience or may be the result of the influence of the teacher, who stimulates the pupil's curiosity through some exercise, reading or lecture, and arouses a desire for further knowledge. Ideally, in all work in general science, the pupil should "Want to know."

While due consideration should be paid to individual interests it is also possible to select units, projects and subjects which are of common interest to all members of a class or section.

The teacher should keep in mind the difference in interests of boys as compared with girls. Boys are interested in great industries, in out door activities, in games, sports, and in general, in affairs belonging to the world of man. The predominant interests of girls are in the home and in the activities within the woman's sphere. Distinctions of this kind must not be taken too literally as boys and girls have many common interests and consequently can frequently co-operate in a common program in general science.

SOCIAL FACTORS.

The pupil today lives in an environment distinctly different from that of his ancestors of three or even one generation ago. A comparison of the extent to which a knowledge of nature and the use of natural forces was prevalent in the early decades of the 19th century with the scientific knowledge and applications of science that obtain today cannot but impress one with the need of some understanding of science and of scientific methods as a basis for appreciation of a very large part of his daily experience.

Man's knowledge of the physical universe has so increased that the possibilities in the way of delightful and satisfying study of natural phenomena and processes are practically unlimited. It may in truth be said that one who has not acquired the habit of observing nature at first hand, and who has not developed an intelligent and broad interest in natural phenomena and in science is virtually deaf and blind; in fact, insensible to large and important areas of experience.

Compare, for example, the satisfaction that a John Muir, an Edison, a Burroughs, or a Gray finds in the nature in which they are particularly interested with that of a person who has never learned to appreciate the rich treasures of nature.

It is eminently fitting that the schools should lead the boy and girl into this fairyland of science, and enable them to see understandingly the wonders thereof.

When one considers the great number of popular articles dealing with nature in magazines and in newspapers, much material in technical journals, numerous allusions in literature, many books and pamphlets on various aspects of scientific study, it is clear that unless one at the same time acquires both an interest and an ability to read intelligently such literature, he is debarred from fruitful and satisfying fields of study.

Bacon's maxim: "Studies serve also for delight" finds ample justification today in the opportunities afforded for mental activity in the realm of science.

On the side of civic education, the dweller in any community, large or small, in order to intelligently understand the interests of that community in protecting and safeguarding its material side, must have interest in and comprehension of the value of expert knowledge of natural phenomena, and of the application of science in the service of man; thus only can he appreciate the importance of adequate fire protection; of a sufficient and pure water supply; means of combatting insect pests, plagues, and disease; the necessity of quarantine under certain conditions; the value of advance information as to weather changes; and the thousand and one appliances whereby human health, safety and comfort are promoted.

Such knowledge should foster appreciation of the value of the expert in public service enterprises where scientific knowledge and application play so large a part. This knowledge on the part of the citizen should so promote a civic intelligence and spirit as will ensure the appointment of capable men instead of politicians for important posts and responsibilities.

A knowledge of scientific facts and principles relating to the care of the human body, viz.—good food, proper ventilation, good sanitation, including protection against insect and other sources of contagion and the control of conditions that threaten health—is essential to a better physical status on the part of the individual and the community.

Much of the scientific knowledge gained in the course in general science will, as a by-product at least, give valuable information to the pupil as to the lines along which his interests lie and in which he is most likely to succeed. It may happen also at times that the knowledge gained and the skill acquired may actually be applicable in the calling on which the pupil enters.

Mental satisfaction and pleasure are enhanced when there exists in any community a large fund of common interest in scientific subjects, since the conversation, discussions, and public conferences in such a community possess elements of interest entirely lacking when there are not such intellectual resources.

On all these grounds, then, a course in general science constitutes an important part in the program of the education of the boy and girl in the early stages of secondary education.

SELECTION OF UNITS

A wide range of units, involving projects, demonstrations, experiments and topics, should be available for use in general science classes. There should be at command much more material than can possibly be used in the time allotted for general science. When the teacher has once grasped the method of gaining material and organizing it, abundant resources will be found.

Out of this abundance the teacher in co-operation with the pupils should select progressively the units for the work of the year. All the content should not be determined or selected at the outset. As the work proceeds the interests of pupils and teachers will suggest new fields of study fruitful in material.

Certain general principles should be kept in mind in selecting units.

1. The problems and topics should appeal to the pupils and be within their capacity to master without undue effort or excessive expenditure of time.

2. Material related to knowledge already at command or connected with actual desire to accomplish is also desirable.

3. As regards the element of interest the skillful teacher will select those factors or aspects most likely to appeal to the pupil. By a natural law of the mind such appeal is best made along the line of previous experience or a knowledge already possessed. The following factors contribute to interest:—

(A). Practical value, including utility, for the individual, for the family, and for the community. Such values appeal strongly. While the purpose of general science is not primarily utilitarian, the teacher may well take advantage of motives based on utility. A pupil making an article of value or engaged in a productive process often gains distinctly cultural results.

(B). Unusual Conditions. Another element that promotes interest is found in the using of projects connected with some exceptional condition, as,—a new water supply; the efforts to control an epidemic; a great fire as indicating need of greater fire protection.

Subjects of this nature that are more or less a matter for public consideration and discussion will be found most valuable and fruitful in suggestion.

4. The elements of any general unit should not be over abstract in character. Generalizations, in themselves, do not appeal

to pupils of this age. In fact, they cannot, in many cases, be grasped in any thorough fashion. At the beginning, the material should be particular and concrete, consisting of individual cases and incidents. After some material of this kind has been mastered the teacher may then lead pupils to establish generalizations, while, in turn, other particular projects and topics may be based upon such generalizations. Once generalizations have been established the way is open for extensive reading.

5. The unit should be rich in content and fertile in suggestion. It should induct the pupil into broad and extensive fields of study and observation. Otherwise his attention becomes diverted, diffused and distracted by meagre and, consequently, disappointing enterprises.

6. The unit in a general science course should be mainly related to local environment, natural or industrial. Such material can be more easily utilized with less expenditure of effort than when one seeks units in a remote field. General science in a rural high school, should include phenomena relating to plants, animals, earth formations, weather changes and household devices. In a city high school the units should relate to extensive and more highly organized applications of science, because these are found in the city environment. Great industrial centers afford units dealing with the use of natural forces in transforming material, in form or in substance.

ORGANIZATION OF MATERIAL.

A teacher accustomed to assign lessons from a text book is very naturally bewildered and at a loss when such ready made material is not available and he must select the content of the study from many sources, including local phenomena and a wide range of books, magazines, newspapers, catalogues and reports. When one considers, in addition, that the pupil is to gain his information in various ways, namely; experiment, observation, demonstration and reading, it is inevitable that unless utter confusion is to follow, the teacher must be actuated by certain definite principles of selection and organization.

General science material should be organized as a number of general units. Each unit should be selected in accord with the aims of general science and should appeal to the pupil as being distinctly worth while in order that he may approach it with interest and purpose. When a pupil once engages in a piece of work which he really desires to accomplish, results are much more substantial than when he is doing something simply because ordered or required by the teacher.

Each unit should consist of a large central theme involving problems or projects, of various kind, so related to the experience and interests of the pupils as to make him feel that their solution is worth while. These problems should of themselves strongly impress upon the pupil the fact that the science of the school and the science of the "outside world" are identical. He should feel that he is learning why things are as he finds them and that scientific knowledge has preceded most of our modern scientific achievement and invention.

The following definitions and terms used in connection with the organization of material are proposed:—

(A). *General Unit.* A main or central theme to be developed by means of undertakings, studies, exercises, by a class as a whole, by the teacher, by individuals or by groups as it seems advisable. Each of these separate undertakings while constituting a definite problem in itself and with a unity of its own will constitute a body of organized material more or less closely inter-related. No definite allotment of time should be made for the completion of the work on a general unit though it may be stated that in general not less than ten nor more than twenty-five class exercises should be devoted to any one unit. The undertakings comprised in a unit include projects, experiments, demonstrations and topics.

(B). *Project.* A project is an undertaking of comparatively limited scope in which a pupil or a group of pupils or an entire class under the direction of a teacher do some definite work in actually making something or in observing or interpreting some phenomena or process included usually in a general unit. (The motive actuating a pupil in working on a project should be based upon definite need or desire. The pupil should seek to achieve an aim of his own motion with self activity dominating in the undertaking). The way in which projects may be performed varies widely and in assigning projects regard should be had to the capacity and interest of the pupil and to the lines of effort and the kind of work which he could follow to the best advantage. Projects are of two kinds:

1. *Construction Projects*: A construction project is one which calls for manual execution either in making a device or machine,

in assembling its parts, in operating such devices or machines or making the same article, or carrying out some processes as for example: making apparatus for wireless telegraph; the pin hole camera; taking photographs with a pin hole camera or regular camera; making a loaf of bread and observing the changes in the process; taking apart a sewing machine and assembling the several parts; taking apart and putting together a camera.

2. *Interpretation Projects*: In performing such a project the pupil observes and interprets some phenomena visible and concrete. He collects information regarding such phenomena by experiment, direct observation, reading or other means which enable him to interpret or explain the object of his study. The pupil should do some reasoning and should gain additional information regarding the phenomena as a result of this reasoning process. Among such interpretation projects may be noted the study of pieces of apparatus such as: telescope; microscope; stereopticon; moving picture apparatus; balances, magnets; mechanical toys; action of yeast; action of baking powder; in these projects the problem in the mind of the pupil grows out of some concrete situation in the field of his observation and experience. Only a small amount of experimental work and that principally for reasons of illustration is needed. Most of the material is gained by reading and observation or presented by the teacher in the form of a demonstration. The pupil in performing such a project should read and otherwise seek answers to particular questions in which his interest has been roused as a result of concrete observation and experience.

(C) *Demonstrations*: A demonstration is an exercise performed before the class or a group to make clear some fact or principle that has been made in working out a project either of construction or interpretation.

Demonstrations are also employed to arouse interest in some particular subject either prior to undertaking a project in that particular field or during the progress of it, as for example: in connection with the study of fire dangers to show the combustible nature of celluloid articles as combs, toys, etc. and the result of bringing such articles near a bare flame or in contact with hot metals.

Demonstrations should, as a rule, be performed by the instructor, but at times the pupil can perform them alone or under the direction and with the assistance of the instructor.

(D) *Laboratory experiments or exercises.* By exercises or experiments is meant a definite piece of work, preferably performed by the pupil for the purpose of establishing some principle or truth or to secure an answer to some problem encountered in a general unit or project or to introduce some unit or project. These experiments or exercises may be performed at home in some cases and in the school laboratory in other instances.

It is obvious that when a pupil is to perform an exercise or experiment without supervision by the teacher he should proceed in accordance with careful directions and with a very definite idea of the object of the experiment.

Laboratory work in a large sense includes observation and recording of data regarding natural phenomena in which the pupil gains or applies knowledge.

(E) *Topics.* A topic calls for the gathering of material by a pupil, a group of pupils or an entire class bearing upon some particular subject. Such material is found in text-books, in popular magazines, newspapers, scientific publications, periodicals, government reports, trade catalogues. The study of a topic should be so directed by the teacher that the reading shall be along definite lines in seeking answers to specific questions and not desultory in character. The reading should be consecutive and should result in substantial understanding of the topic studied.

Topics as a rule deal with subjects of too large and complex a character to be limited to the direct observation or experience of the pupil. Constant reference usually should be made to the scientific principles involved and the pupils should be directed to read along lines suggested by the study of concrete cases. From time to time experiments can be made by the teacher to make clear some principle or process that otherwise might not be secured. As examples of topics there may be cited the following: water supply systems; street car systems; local telephone systems; eclipses of moon or sun; phases of the moon; hot and cold water supply in the home; combustion in the locomotive; concrete construction; local drainage, including sewage; fertilizing for crops; ice age in New England; work of Burbank; story of Pasteur and bacteriology; invention of the steam engine. Local illustrations should be used in every case to give zest and interest to the reading. If the reading gets far away from the experience of the pupil there is likely to be a loss of interest and of clear understanding of the material read.

When these units and projects are wisely selected and well organized the pupil should find something in each which arouses his genuine interest and which challenges his best efforts. While at times the several problems on which the class may be engaged in a given unit may seem to be unrelated, at the close when the results are combined the relation of each part of the main unit should be clearly seen.

While each project or problem in a given unit should be complete in itself, cumulative effect is produced by grouping together a number of projects belonging in the same field of natural phenomena or process. Unless there is some such relationship the result will be a number of isolated and comparatively limited projects and undertakings whereby a pupil is not led to group the knowledge and experience given under any general heads. The result is frequently a dissipation of interest and distraction of attention. General science should abound in effects, phenomena and processes likely to appeal to the interest of the pupil and to be within range of his comprehension.

There are given herewith certain suggestions regarding units and projects, demonstrations, laboratory exercises and topics in each unit. Not in any sense is this to be used as a syllabus, but only as indicating the fields of study open to pupils in general science.

I. *HEAT IN THE HOME.* (General Unit).

- (a) How do we produce heat? (Project).
    - 1. *Gas Stoves*:
        - How should the stove be adjusted and lighted?
        - Compare with Bunsen burner, plumbers' torch, steam automobile burners, some alcohol lamps, camp stoves, Welsbach lights, etc.
        - How much does it cost to operate the stove?
        - Can you measure the heat obtained from it?
        - How may it be run most economically?
        - How is gas produced?
    - 2. *Oil Stoves*:
        - What different kinds are there? What are the good and bad points of each?
        - How much does it cost to cook or heat with them as compared with gas stoves?

How do they affect the air in a room?
What is "oil"?

3. *Coal Stoves*:
   What make of range is best?
   What is the best coal stove for heating purposes only?
   How does the cost of operation compare with gas?
   What is coal?
   What size is best to buy?
   What is the best way to buy coal?
   Why do we use wood and charcoal in starting the fire?
4. *Fire Places*:
   Are they good heaters?
   What fuels are used?
   When and where were fire places first used?
5. *Furnaces*:
   How do they heat a house?
   What are their good and bad qualities?
6. *Steam Heaters*:
   How do they heat a house?
   What are their good and bad qualities?
   What is the use of the pressure gauge?
   What is the diaphragm?
   Why is the water glass used?
   What is the purpose of the safety valve?
   How does it work?
   How is it that the air valves let out the air but prevent the steam from escaping?
   Steam enters the radiator at a temperature of 212° F. Water leaves the radiator at a temperature of 212° F. Where does the heat come from that heats the room?
7. *Hot Water Heaters*:
   How do they heat the house?
   What are their good and bad qualities?
   Which kind of heater would you select?

(b) How do we regulate the heat? (Project).

1. *Dampers.*

        - How are they used to regulate the heat—in a stove; in a furnace? (Why are there no dampers in a gas stove?)
        - How are they automatically changed on a steam heater?
    2. *Thermostats.*
        - How do they work?
        - Are they reliable?
        - Are there any disadvantages?

(c) How is heat distributed?
    1. *Registers.*
        - Should they be placed in the wall or the floor?
        - Why doesn't the air come up through all registers equally?
        - Can this unequal distribution be remedied?
        - What makes the air come up at all?
    2. *Radiators.*
        - Why are they called radiators?
        - Where should they be placed?
        - Does the nature of the surface or the color of the paint affect the heating quality?

(d) How is heat lost?
    1. *Hot Water Tank.*
        - Do we get the hot water from a tank "for nothing"?
        - Is it better to have it connected to a stove, house heater, or special gas heater?
        - How does the water get heated?
        - How do the materials used affect its efficiency?
        - Should it be connected directly to the city water supply?
    2. *Flue Gases*:
        - How much heat goes "up the chimney"?
        - Is there any way of preventing it?
        - Why is a furnace a wasteful contrivance?

(e) How can we save heat?
    1. *Fireless cookers*:
        - How are they made?
        - What material is best for packing the walls?
        - How can the efficiency of the cooker be tested?

Has it any advantages besides saving heat?
Can it be used for anything besides cooking?

2. *"Thermos" Bottles*:
   How do they differ from fireless cookers?
   Are they more or less efficient?
   Are they worth while in the ordinary home?
3. *Burning Ashes*:
   Is it a good plan to buy preparations to mix with ashes that they may be burned again?
4. *Covering Pipes*:
   With what are steam pipes covered?
   How is heat saved by the covering?
   Why are water pipes sometimes similarly covered?
   Why aren't furnace pipes covered in the same way?
5. *Stove Pipe Heaters, etc.*
   Are the heaters which are attached to the stove pipe of the range valuable?
   Do we get more heat from these than from the stove pipe directly?
   Do heaters sometimes placed on gas lights really save heat?

(f). How can we get rid of heat?

1. *Refrigerators*:
   What material is best for the interior?
   Where should the ice be placed?
   Would a refrigerator which kept the ice from melting be ideal?
2. *Ice Cream Freezers*:
   How is the cream frozen?
   Why is salt used?
   How low a temperature can be obtained with such a mixture?
   Could any other be used?
   What is the use of the dasher?
   Why does the cream sometimes poison us?
3. *Ice houses*:
   Why is sawdust used?
4. *Cold Storage Plants*:

(g) Chafing dish fuels.

1. *Alcohols*:
   - What is the difference between grain alcohol, wood alcohol and denatured alcohol?
   - How can you tell them apart?
   - How can you tell by test which one gives the most heat?
   - Is the one which gives the most heat the best one to purchase?
2. *"Canned heat"*:
   - How do the solid preparations compare with the alcohols in efficiency, cost, etc.?
   - Would it pay to buy them?

(h) Too much heat.

1. *Fires.*
   - How do rubbish heaps tend to cause fires?
   - Houses have been set on fire by closing registers. How could this happen?
   - What is "spontaneous combustion"?
   - How do mice sometimes start fires?
   - Are there any other common ways in which fires are started?
2. *Fire Extinguishers*:
   - What different kinds are there?
   - Are they effective?
   - What kind should be kept in the house?
   - How does water put out a fire?
   - What should be done when a person's clothing gets on fire?
3. *Burns*:
   - How should burns of various kinds be treated?
   - Why does steam cause a more painful burn than a hot stove?

NOTE:—The foregoing questions under each head indicate lines of investigation. The pupils will doubtless suggest many more. While the teacher must expect some of these suggestions to lead into other and remote fields, and be liberal in considering such, he is under obligation to use good judgment as to the proper limit to such excursions into by-paths.

(*To be continued.*)

Fundamental Considerations in the Reorganization of High School Science

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There has never been a time in the history of secondary education when consideration of the fundamental principles underlying high-school science courses was as necessary as at the present hour; nor has there been a time when those principles were receiving the attention they are now receiving. The Spencerian conception of science as a foundation for all general education has not been realized. The popular interest in science which characterized the epoch of Darwin, Huxley, and Agassiz, of Faraday, Lyell, and Tyndall has largely waned in recent years. The last decade of the 19th century and the first decade of the 20th century showed a marked decrease in the *percentage* of high-school students enrolled in the science classes of the secondary schools of the United States. Meanwhile, *applied* science advanced by leaps and bounds. Its controlling influence in the daily life activities of all classes increased at a tremendous pace. Within a life's span it has completely revolutionized all systems of transportation and communication; it has all but annihilated time and space; it has molded all civilized peoples into a single, interdependent community; it has transformed the primitive home into the modern home with its multitude of labor-saving and life-conserving conveniences; it has, in a large measure, severed the fetters of hard manual labor from the farmer, the mechanic, and even from the common laborer; it has enabled man to subdue and harness the vast, wild forces of nature to an extent undreamed of by the Jules Vernes of a half-century ago; it has multiplied the productive resources of human effort many fold; in short, it has doubled and redoubled the available comforts and pleasures of life and, at the same time, it has cut in half the necessary hours of human toil.

In such an age, when applied science rules the activities of men, when all human activity is so dominated and determined by applied science, why should not popular interest in science be ever increasing? Why this decline in the percentage of students who are pursuing the science courses offered in our high schools? Why the present unrest and agitation by science teachers and students of education concerning science instruction in our high schools?

Why the persistent demand, from every quarter, that high-school science be reorganized?

If science is ever to become the basic foundation of a general education for the common people, as was held two or three generations ago to be inevitable, not only by Herbert Spencer, but also by many of the leading educators of that day, science in our high schools must be reorganized. It must be reorganized with a conscious recognition of the fact, that we are now living in the 20th century, that we have passed the period when initial interest in science rests with a mere appreciation of the great, general, abstract truths of science, if indeed, young people of high school age ever were interested in that phase of science. Today, the world, outside the school room, thinks in terms of applied science, of practical science. It is absolutely clear that at the present time our classroom instruction must reveal to the high-school student something of the story of the discovery of the great truths of science but especially it must make clear to him the monumental effects of applied science upon modern life.

The science courses offered some thirty to forty years ago, when the public high school was in its infancy, were interesting and popular. But the courses then offered were largely of the nature of popular science; they were spiced through and through with details and illustrations of interest to the common people. Some of us are inclined to smile at those early courses today because they were so brief, because they dealt so largely with the spectacular side of science, and possibly even because they were evidently so framed up as to make a strong appeal to the interest of the young people. On the other hand, students of education are coming to recognize that the greatest value of those early courses lay in the appeal they made to the interest of the student.

Gradually elementary courses in science became more and more barren of detail and almost devoid of those touches of human interest which made the earlier, popular presentation fascinating. Gradually, but surely, high-school science became a condensed epitome of the college course; the dry bones of the college course were presented but the flesh and blood were gone, and with the flesh and blood went also the interest of the student.

The present organization of science materials into the special sciences for purposes of instruction, in the early years of the high school, at least, is fundamentally unpedagogical and is largely responsible for the decline of interest in science in our secondary schools. The usual course in any special science either presumes that the student is interested in the abstract, fundamental truths of science or else it neglects the element of interest as a factor in the educational process. In either case it is unpedagogical and a fatal mistake, for initial interest in science rest chiefly, if not solely, in those phases of applied science which have to do with the control of our environment, and without interest little educational progress is possible.

The units of applied science are fundamentally different from the units of "pure science." The units of applied science are the natural, Creator-made, units; the units of pure science are artificial, man-made, units. Because the mature scientist appreciates and sees a certain significance in the organization of science materials into man-made units, it does not follow that the boy or girl just beginning the study of science is likewise interested in such a so-called "logical" study of abstract, fundamental principles. The adolescent is distinctively an embodiment of alert, intense impulses. But with all his keenness and alertness his interest is secured and maintained only when the subject under consideration has significance, when it has direct bearing upon his welfare or the welfare of those about him. Critical analysis, long continued, followed by synthesis, and finally terminated, possibly, by a brief mention of application, *which is the method of a special science,* may satisfy the mature scientist but such a procedure kills all interests in the beginning high-school student. The beginner in the study of science is interested only when the order of procedure is reversed. He wants, first of all, to see the *go* of things; he must first of all be shown the worthwhileness of the task set before him. This can be accomplished only by showing him the significance of science in its applied setting. Out of a study of applied science all essential laws and principles may be developed.

As a concrete example of the foregoing let us consider the procedure of special science organization of plant life, botany. Where is the wide-awake, fourteen-year-old farmer boy who is interested in a two or three-week analytical study of roots, followed by a similar study of stems, then of leaves, and finally of fruits even though some mention of application may be made in the closing chapter? Such a boy, however, with red blood in his veins, is intensely interested in the study of corn, or of wheat, or of potatoes, the conditions under which they germinate or sprout, and under which they grow and mature. He is interested in the climatic conditions and the soil conditions best suited to their growth and maturity, and in the insect pests to which they are subject. When science teachers come to recognize that the source of interest for the high-school boy lies in the applied phases of science and not in the abstract phases, or "pure science" phases, they will cease to wonder at the fact that agriculture is popular and on the incline as a high school subject while botany, as generally taught, is unpopular and on the decline.

The mastery (?) of some two or three hundred abstract principles and laws, together with the solving of several hundred mathematical problems and the performing of fifty or more generally non-significant laboratory exercises is usually recognized as the sum total of an adequate high-school course in physics. Such a course has been the bane of life and the Waterloo of thousands, if not millions, of perfectly normal high-school girls. Their frantic efforts to surmount this obstacle to their goal, graduation, is pathetic. But who will say that the average girl cannot be interested in, and led to appreciate and to understand, the essential principles of that most difficult portion of physics, mechanics, when we see her sitting confidently at the steering wheel of the family car safely guiding it through the crowded thoroughfare of the city? The fact is that she is easily capable of intense interest in gears, in revolutions per minute, and in differentials, as well as in proper mixtures, induction coils, magnetos, spark plugs, and storage batteries provided these be taught, not as abstractions, but as vital parts of the car she drives.

But the question arises, Just how is this reorganization of science upon the principle of developing the essential laws and principles out of a study of applied science to be effected? Or again, Is it possible to organize science materials, while following such a plan, into logical units of instruction having educational value?

Time and experience alone can fully answer the first of these questions. At the present time, however, a partial answer, and answer so far as the first course in science is concerned, is being worked out. Some of the one-year courses in general science now available is the tentative answer. Natural science, *organized knowledge concerning nature,* is not a static thing; it is ever changing; it is ever expanding and presenting new insights and new problems concerning human welfare. Likewise, no course in general science can long remain static; it must be modified and adapted to the ever changing content of our knowledge concerning the natural world about us. Nevertheless, certain fundamental principles of organization would seem to be permanent and abiding. It is the purpose of this paper to point out some of those permanent fundamental principles.

SCHEMATIC OR GRAPHIC ILLUSTRATION OF THE ORGANIZATION OF SCIENCE COURSES.

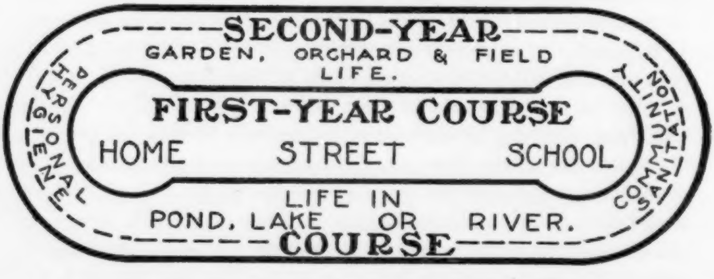
Unsatisfactory and incomplete as it must necessarily be, schematic or graphic illustration of courses of study is frequently of value because it gives at a glance the essential features of the organization. A common organization of science courses, as they have been arranged in the past, is shown by the following:

1st Year		2nd Year		3rd Year		4th Year	
Phys. Geog.	Physiol.	Zoology	Botany.	Physics	Physics	Chem.	Chem.

The Biology Committee of the National Educational Association presented the following scheme at the meeting in July, 1916:

General Course Required				Elective Courses	
1st Year		2nd Year		3rd Year	4th Year
Physical Science	Plant Life	Animal Life	Man	The Special Sciences.	

Such an organization as is presented in either of these schemes has aptly been styled a "vertical stratification of science". In contrast to any similar organization of science courses we suggest the plan shown in the following diagram, as indicating the field or scope of general science courses covering the first two years:



Such an organization of science presumes that the science materials for the first year's course shall be selected chiefly from the applications of science as found in the home, in the school and along the street leading from the home to the school. Naturally, physical science materials, such as lighting and heating systems, refrigeration, water supply and sewage disposal, the use of labor saving machines, together with the weather, climate, food and nutrition, microörganisms, and similar materials will chiefly comprise the course and personal and community welfare will be the crucial point of attack. The second year's course will reach out on every side for materials and will include plant and animal life as found in the garden, the orchard and the field, in the pond, river, or lake. It will also include a more complete study of personal hygiene and community sanitation. The second year's work will, therefore, deal chiefly with biological materials although the influence of physical environment will everywhere be an important consideration.

Science materials as commonly organized in the special sciences may properly be said to be organized into man-made units while the materials in general science may properly be said to be organized into Creator-made units. Nature presents no fundamental relationships, no functioning activities, which necessitate the study and comparison of all the forms and variations of roots, then of stems, then of leaves, and finally of fruits before a student may proceed to study and acquire an understanding of the essential characteristics of the corn plant and of the conditions best suited for its growth and maturity. Nature presents as a logical unit of study the *relation between* the root of the corn, the stem of the corn, the leaf of the corn, and the fruit of the corn. The entire corn plant, together with its relation to the soil, to moisture, to climate, and to the animal life which affects its growth is the natural, Creator-made unit. A study of corn, then of wheat, then of clover, then of the potato, then of the beet, then of the onion, and so on, until the plant life of the student's environment enables the student to grasp all of the essential principles taught in special science and at the same time approaches the various problems along the line of his natural interests.

Similarly, there is no intrinsic value to the girl in the study of all forms of gears, and all the various systems employed in the transmission of mechanical power before she is permitted to study a concrete case. The girl who drives a car is certain to be interested in the transmission system of her own car and she delights in obtaining such a knowledge of it as will enable her more completely to control her car as a result. But the real unit of study which appeals to her as logical and natural includes the essential mechanical features of the car; it includes not only the transmission system, but it includes as well the source of power and the controlling devices; it includes proper mixtures, proper timing of ignition, spark plugs, magnetos, and storage batteries as well. Moreover, she must see all of these in their proper relation to each other. Such an organization is the Creator-made unit, the unit of applied science. Such an organization presents the unit which has significance and therefore is of interest to her. Such an organization may properly be called a "horizontal stratification of science" in contrast to the "vertical stratification of science" as presented by special science.

There is positively no difficulty in organizing the science materials involved in such courses into suitable, logical units of instruction of as great, if not greater, theoretical educational value as the usual units of special science. In addition, experience shows the writer that such an organization of science materials secures and holds the interest of the student with the result that a permanent, abiding interest in science is developed and a permanent scientific attitude of mind results.

It is as yet a question whether the recommendation of the Biology Committee, that the last two years of the high-school course shall be devoted to the study of elective special science, is the best possible solution. It is doubtless true that with greater maturity and with fuller knowledge of the significance of science there comes a time in the life of each of us when we do develop an interest in the abstract, philosophical aspects of science. Whether that stage is usually reached by the student when he enters upon his junior year of high school work is a question. Many students of education doubt it. In any case it would certainly seem wise that in most high schools specific courses in agriculture, domestic economy and household science should find a place in the last two years of high-school course.

THE SPECIAL SCIENTIST'S CONTENTION.

The contention is made by some of the advocates of special science that the reorganization of high-school science along the lines here proposed means the reversing of the wheels of progress in all science teaching. It has been generally admitted that science instruction in our high schools has been at least a great disappointment, if, indeed, not a near failure. The special science teachers in colleges and universities have been bold in declaring that the work done in the high school has to be done over again in the college classes; they say that there is really little difference in the progress made by those who have had the high-school work and those who have not. But some of the advocates of special science insist that we are just now at the turning point; they say that we are just now realizing our mistakes, that we have just discovered how to adapt the subject matter and methods of instruction so as to secure and hold the interest of the students and to teach science courses successfully. In short, they say that we have just learned that special science courses must be humanized. Moreover, they point out the fact that all college and university instruction prepares the young high school teacher to teach special science. "If these teachers have not made a success of teaching special science in the high school", to quote the thought of one of their most distinguished leaders, "the mess they would make of it were they to attempt to teach general science must be left to the imagination." In general, they say that to abandon the teaching of special science, in a part or all of the high-school course, and adopt the general science organization would mean the forfeiture of the progress made, and a loss of the benefit of the experience gained, during some two or three generations of science training and science teaching and to turn a well-ordered, logical system of instruction into confusion and chaos.

THE ANSWER.

These champions of special science have not yet proved, nor do we believe that they can prove, that any of the special sciences as now taught in the high school are gaining materially in interest, popularity or effectiveness. Nothing is more evident than that physical geography and physiology, commonly first year science courses, never before suffered so great a decline as during the past two years. First-year general science has already largely displaced them. Botany and zoölogy are, in many sections of the country, giving place to agriculture. The record of higher institutions requiring elementary physics and chemistry for entrance to certain courses show an ever increasing percentage of applicants knocking at their doors without these prerequisites. If special science courses are really gaining in popularity, interest or effectiveness, available records do not reveal the fact, nor does the testimony of students, science teachers and administrative officers reveal it.

Again, however true the contention may be that college and university courses in science prepare the young teacher for teaching special science only, this fact does not justify the retention of such courses in the early years of the high school, if our contention that such courses are unsuited to the interests and needs of beginning high-school students is valid. If special science is not in harmony with the foundation principles which underlie successful science teaching in the early years of the high school, the remedy lies only in a readjustment of the science courses in such colleges and universities as aspire to prepare high school science teachers. The public high school exists for the benefit of the children of the common people; it must be so organized as best to serve the interests and welfare of the millions of young people who must complete their education within its doors. If the usual courses in special science now offered by the higher institutions do not prepare the teacher to teach general science, colleges, universities, normal schools, and teachers colleges have no alternative but so to adjust their courses that their graduates *can* properly handle the courses required by the high school. The higher institution cannot longer expect to dictate the courses and the methods of instruction in the high school but must so prepare teachers that the best interests of the high school may be conserved.

It is not certain, however, that teachers fairly well prepared to teach the special sciences cannot also teach courses in general science with fair success. In all the smaller high schools, the country over, science teachers are now teaching, not a single science, but often all the sciences and frequently other branches, such as mathematics, literature or history. It is common practice to require the science teacher in such schools to take charge of the work in agriculture or domestic science. Furthermore, during recent years, courses in general science have been taught in many schools by these same teachers trained only in special science. That such courses in general science are being continued year after year and are, in general, being pronounced a success would seem to be a sufficient contradiction to the statement that our present corps of science teachers are not fairly well equipped to teach general science.

SUMMARY.

It is our contention that special science in the high school has been a disappointment, if not a near failure, not chiefly on account of poorly prepared teachers but chiefly because the selection and organization of subject matter and the methods of approach and development have been fundamentally unpedagogical. The natural interest of the student just beginning the study of science lies in the applied phases of science as it affects his own personal welfare and the welfare of the community in which he lives. The fourteen-year-old boy or girl is not a philosopher; abstract generalizations and principles of science, that is, special science as usually taught, so-called "pure science", is foreign to his interests and his ways of thinking and is therefore distasteful to him. Only the genius, the teacher of unusual personality and ability, and who is inspired by his own devotion to the subject can interest a class of beginners in that phase of science. The ordinary teacher, on the other hand, who is fairly well prepared in the academic phases of science, can succeed fairly well with the beginning class if the materials are organized as general science and the materials selected deal with the applied phases of science as found in the environment of the student, because he then has the natural interest of the student to aid him.

The reorganization of high-school science in substantial conformity with the fundamental principles here set forth seems certain to come in the near future. Live science teachers, administrative officers and students of education are everywhere studying the question with interest and sincerity. The exact form of the reorganized courses will be determined only by time and experience but the fundamental principles upon which the reorganization will rest appear to be pretty well established.

Twilight

By W. G. WHITMAN, State Normal School, Salem, Massachusetts.

Anyone who has ever been in a brilliantly lighted room when all the lights have suddenly gone out, understands the bewilderment and feeling of utter helplessness which comes to one whenever there is a sudden and unexpected change from light to darkness. With this thought in mind we can better appreciate the beneficient effect of our atmosphere in causing a gradual merging of day into night. Were it not for the atmosphere about the earth, when the sun sinks below the horizon we would be plunged instantly into dense darkness. We would need to light all our houses at once. An entire city would be lighted at the instant of sunset or earlier. How different that would be from the leisurely manner in which we are now able to do our lighting. With the exception of cloudy days, it is light enough after sunset for a good deal of work or play without the use of artificial light.

It is an interesting spectacle to look down upon a town just after sunset from a neighboring hill. At first a solitary light appears now here, now there. Later their number increases rapidly until nearly all the houses and streets are dotted with lights. All this happens and it is still light enough to see the path down the hill to town. In the indistinct light of evening details are softened, mysteries abound, and the charm of it all fascinates us. Poet and artist have been inspired by it and have recorded their emotions in verse and painting. The frontispiece "Evening Twilight" in this number of the Quarterly is from Charles H. Davis' "Evening", a painting which hangs in the Metropolitan Museum of Art in New York.

O Twilight! Spirit that dost render birth
To dim enchantments; melting heaven with earth,
Leaving on craggy hills and running streams
A softness like the atmosphere of dreams.*

Twilight summons the owl, the night-hawk and the whip-poor-will to activity. Twilight brings forth the frog's song and awakens the katydid. Morning twilight is the one time of the day for the greatest rejoicing among the birds; then it is that the bird lover goes out if he would be present at their music fest.

There are certain flowers, too, which seem to be inspired by twilight, at least they are stimulated to open their blossoms and to pour forth their fragrance at that time. As some of our most beautiful flowers are only found skirting the perpetual frost, so others are never found except they are sought along the borderland of night. Have you ever had the pleasure of watching the buds of the evening primrose unfold into blossoms at dusk? How quickly the air becomes laden with sweet fragrance! Perhaps you have seen the sweet-scented evening stock, which has been drooping

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*From poem by Caroline E. S. Norton, (Lady Maxwell).

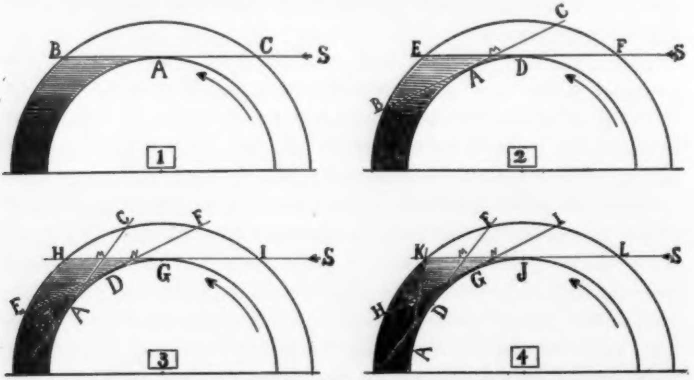
listlessly all day, straighten, blossom, and pour out its delicious perfume upon the cool twilight air. Nicotine, inconspicuous with its limp and lifeless trumpets during the day, attracts your attention in early twilight by its penetrating fragrance and its beautiful white star-tipped trumpets. These evening flowers are visited by moths and humming birds; the fragrance aids in attracting their attention.

If you are not naturally curious about natural phenomena, you probably never have questioned the source of this light which is not only so useful but so pleasant to us at the close of day, which so cheers the birds in the early morning, and which makes the blossoming time of some of our most fragrant flowers.

When the sun has gone below our horizon we are in the shadow of the earth; but the air above us does not pass into this shadow at once. As long as some portion of the atmosphere above our horizon receives light direct from the sun, the particles of dust and moisture in the air will reflect more or less light into the shadow to us. This reflected and diffused light is called twilight. A similar twilight occurs before sunrise in the morning. The morning twilight is commonly called dawn. Above forty miles the air either is so rare or so lacking in suspended particles that no sensible light is reflected.

The boundary line between the illumined atmosphere and the darkened portion below it, is sometimes so marked that it may be observed. Soon after sunset this curved boundary line known as the "twilight bow" may be seen to rise in the eastern sky. It has a reddish color and diminishes in intensity, usually disappearing before it reaches the zenith. As the twilight enchanter sweeps the sky with this magic wand a veil is drawn aside and behold: the marvel of night is disclosed with her thousands of sparkling eyes.

The transition from day to night through twilight is so gradual that the bounding limits cannot be told except by indirect means. Twilight begins at sunset, but we see no sudden change in light at that time. When the eastern limit of the illumined atmosphere is at our zenith first magnitude stars are visible in the eastern sky. Toward the end of twilight the sky is dark except that a faint glow of light may be seen near the western horizon. Twilight ends when sixth magnitude stars are visible in the zenith. At the end of twilight the sun is about eighteen degrees below the horizon. In Europe the term *civil twilight* is applied to that portion of twilight in which it is light enough to continue outdoor occupations. Civil twilight ends when the sun is about 6° below the horizon. Occasionally a glow is seen in the west after true twilight has ceased. This "afterglow" is thought to be doubly reflected light; that is, light reflected from twilight into darkness.



Figures 1-4. Source of Twilight. The depth of atmosphere is greatly exaggerated. If drawn to scale, A in Fig. 4 would be approximately 18° from J.

In Figures 1-4 the earth's surface is represented by the inner semi-circle and the atmosphere by the space between the two semi-circles. Let A (Fig. 1) be a point on a broad plain of the earth's surface and BC the horizon. The last rays of the setting sun are on the horizon line. All the atmosphere above the horizon of an observer at A is in direct sunlight. Because of the eastward rotation of the earth the observer at A is quickly moved from the daylight zone into the shadow and the twilight bow begins to rise in the east. When the point A has reached a position shown in Figure 2 the observer receives diffused light from the upper layers of air included by EMC. The lighted space above the observer's horizon is ever diminishing; when the observer has reached a position, A, shown in Figure 3, he receives light only from HMC. Finally his horizon line toward the west passes outside the lighted portion of the earth's atmosphere (Fig. 4) and twilight has ended.

The duration of twilight varies greatly in different parts of the world; it also varies in any one given place. The length of twilight depends upon the condition of the atmosphere, the elevation, the season and the latitude.

A clear atmosphere devoid of all particles of dust and moisture has little power to reflect light. The number of these particles varies and so the amount of light reflected into the earth's shadow varies. A decrease in the intensity of reflected light shortens the twilight.

The height of overlying air capable of reflecting light is less on a mountain top than it is at sea level. Because of this and the fact that in mountainous regions the air is very clear, twilight on high mountains is short. On some mountains in the tropics twilight is reported to be less than twenty minutes in duration. Just east of a high range of mountains or in a deep narrow valley twilight is short because of the limited extent of illuminated sky above the horizon.

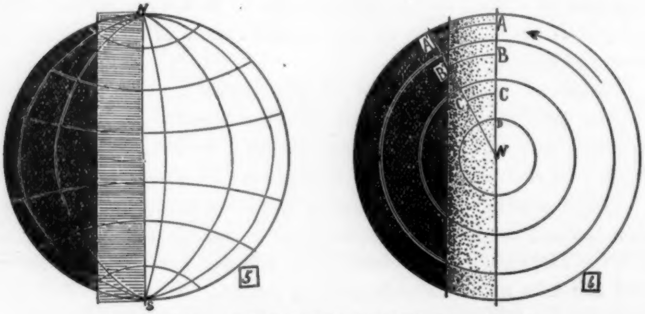
Because of the inclination of the earth's axis to the ecliptic and the variation in the time it takes for the sun to reach a point eighteen degrees below the horizon, twilight varies at different times of the year and varies with the latitude of the observer.

Figures 5 and 6 show the earth in spring and fall at the time when the length of daylight equals that of the night and twilight together. Daylight reaches both poles and a belt of twilight nearly 1500 miles in width extends entirely around the earth. This belt is bordered on one side by daylight and on the other by darkness. Figure 6 is a view of 5 as seen when one looks down on the north pole. The outer circle represents the equator. Let us consider three places A, B, and C, which are in different latitudes and which are just entering the twilight belt. These three points describe complete circles in 24 hours; it is evident that A, since it describes the largest circle, moves faster than B, and B moves faster than C. When B has just crossed the twilight belt and reached the point B′, A had reached A′ and C had reached C′. It is thus seen that a point on the equator passes through the twilight belt quicker than any point either north or south of it. Kipling suggests the brief twilight of the tropics thus:

> "An' the dawn comes up like thunder outer
> China 'crost the Bay."

Any point within 18° of the poles such as D remains in the twilight belt 12 hours on March 21 and September 23.

A study of Figures 7-10 will readily show that as a result of the difference in the relation of the sun's daily path to the horizons of observers in different latitudes that the distances the observers traverse in order to cross the twilight belt vary with their latitudes. For example, compare the distance that A must travel with that which B must travel to cross the belt (Figures 8 and 10). Even if their rates of motion were the same, the time required to cross the belt would be greater in the higher latitude because here a point on the earth passes more obliquely across it. In polar regions a point may not cross the twilight belt, but instead describe a circle partly in it and partly in darkness (D in Fig. 8) or it may describe a circle partly in twilight and partly in daylight (D in Fig. 6 and C in Fig. 10).

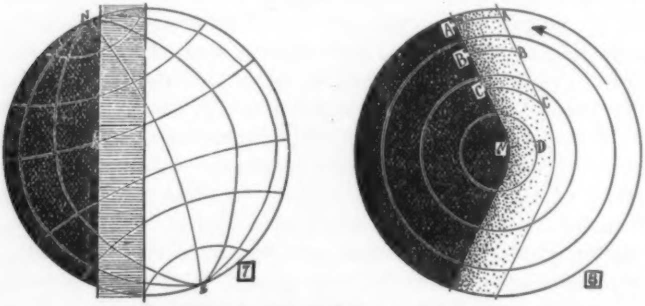


Figures 5-6. Twilight Belt in Spring and Fall.

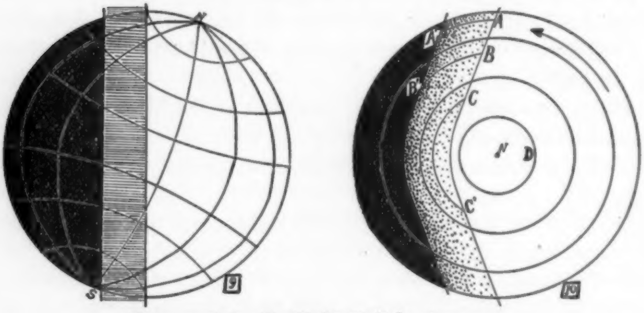
The twilight belt migrates back and forth across the poles. On December 22 the north pole is in darkness (Fig. 8). A few weeks later it enters the twilight belt, in which it remains until March 21 (Fig. 6). On this date it enters a six months' period of sunlight (Fig. 10). On September 23 the pole again enters the twilight belt (Fig. 6) which it crosses in a little over two months. During the latter part of this twilight period it is darker than during the first part of it, but the reverse is true when the pole emerges from darkness and approaches the daylight.

In latitude 42° twilight is longest in June when it lasts about two hours; it is shortest in February-March and September-October when it is less than one and a half hours. In latitude 50° twilight is more than three hours long in June and but little over one and a half hours in February-March and September-October. That twilight is longer in December and January than it is in the months preceding and following is due to the fact that we pass through the twilight belt more obliquely in winter than we do in early spring and late fall. This can easily be understood by reference to the diagrams (Figs. 6 and 8).

In low latitudes there are two twilights in twenty-four hours but at the poles there are only two twilights a year; and these are several months in duration. In some latitudes between these there are places where evening and morning twilights blend, making one twilight each twenty-four hours (C in Fig. 10 and D in Fig 6.). In England there is no real night from May 22 till July 22. Daylight and twilight make up the 24 hours of the day. Perhaps this is one of the most interesting experiences the newly arrived American has in England when he reaches that country in June. For then he is able to read a daily paper on the street as late as 9.30 P. M. without artificial light. In latitude 60° it is light enough in summer to read large type during the entire "night", which is not true night at all but only twilight.



Figures 7-8. Twilight Belt in Winter.



Figures 9-10. Twilight Belt in Summer.

What the Chemist Can Do for Medicine*

By Alfred W. McCann, New York.

Do pathogenic organisms (tuberculosis, typhoid fever, scarlet fever, diphtheria, septic sore throat, etc.) thrive or die in blood, the specific gravity of which is normal? If any living chemist or bacteriologist could answer this question tonight he would stand forth the most conspicuous member of his profession.

It is now definitely known that the specific gravity of the blood can be changed at will through the instrumentality of diet. Minerally deficient food affects with extraordinary rapidity the specific gravity of all the internal secretions. Animal experimentation, conducted in hundreds of laboratories throughout Europe and America, yields abundant data with respect to this phenomenon, the significance of which has been ignored by the medical profession and the biochemist.

It is now known that the functions of the mineral substances found in the internal secretions may be summarized as follows:

1—To regulate the specific gravity of the blood and other fluids of the body.

2—To regulate the chemical reactions of the blood and the various secretions and excretions.

3—To preserve the tissues from disorganization and putrefaction.

4—To enter into the permanent composition of certain structures, especially the bones and teeth.

5—To enable the blood to hold certain materials in solution.

6—To serve special purposes, such, for example, as the influence of chlorine on hydrochloric acid formation, the influence of calcium in favoring coagulation of the blood, the influence of iron in the formation of blood pigment, the influence of potassium on the elasticity of the tissues, etc.

That it has never occurred to the medical profession to note the changes that take place in the specific gravity of the blood and other internal secretions or to interpret the significance of such changes, constitutes one of the curious lapses of the scientific world. It is known that in anemia, cup-shaped corpuscles are found. Anaesthesia also produces cup-shaped corpuscles. In fevers the

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*Address before the Chemistry Teachers' Club of New York City, in October, 1916.

corpuscles are wrinkled or cerated. These facts are significant in connection with the popularly accepted theory that the red corpuscles of the blood always appear as discs, slightly hollowed on each side.

Physiologists have noted cup-shaped red corpuscles, concave on one side and convex on the other. Failing to interpret the shape of the corpuscle as a symptom of some change in the specific gravity of the blood, they have announced what they believed to be discoveries concerning their true shape. Arey, of the Northwestern University Medical School, reports experiments which prove that the form of the corpuscles depends on the density of the serum in which they float.

Normal, freshly-drawn blood has disc-shaped corpuscles. When diluted with 40% water the corpuscles of normal blood become cup-shaped, possibly for the reason that the dilution causes them to swell. When 70% water is added to normal blood the corpuscles swell until they become spheres. By withdrawing water from the serum the corpuscles shrink until their margins become wrinkled. If corpuscles thus change their shape, due to the absorption of water in one case and the giving up of water in the other, to what extent does the change of shape, due to the altered specific gravity of the fluid in which they are bathed, modify their functions?

Normally fed animals in whose diet appear the salts and colloids of calcium, potassium, iron, phosphorus, manganese, magnesium, sodium, sulphur, silicon, chlorine, fluorine, iodine, are able to develop immunity to many diseases. We are quite certain that all forms of malignant diseases are possible only because of the absence of or loss of this immunity. The experiment stations of Europe and America have clearly established the fact that all animal life in normal state of environment and supplied with nutriment containing all the organic ingredients necessary for the upbuilding and maintenance of a disease-resistant vitality, possesses in itself a protective immunity to cancer.

The hundreds of experiments (such as those of Voegtlin and Towles) with foods of high caloric value deprived of their mineral salts demonstrate the inadequacy of such foods. One-sided nutrition with refined carbohydrates, proteins and fats is followed by immediate reactions in the internal secretions. Deprive the living organism of the mineral salts found in these secretions and the specific gravity of the blood must undergo a morbid change.

If this change is followed by a mangling, strangling, withering or bloating effect upon the corpuscles, to what extent do the corpuscles, under such conditions, both fail to perform their natural functions and set up possible morbid activities which destroy equilibrium?

The chemist, particularly the biochemist, has in the field of nutrition an opportunity to enlighten the medical profession with respect to the significance of the morbid conditions that follow a disturbance of the normal specific gravity, not alone of the blood but of all the internal secretions.

The extent to which natural immunity may depend upon the specific gravity of the blood has never been suspected. The extent to which the unnatural modification of the shape of the normal red corpuscle may influence the vitality of the human organism has never been suspected. The results of hundreds of experiments, indicating the general necessity of unmilled, unrefined, undenatured foodstuffs in the diet of man and animal, are on record. The manner in which these results are ignored by the modern dietician as well as by the medical profession is undoubtedly due to the failure of chemistry thus far to determine the exact significance of the specific gravity of the normal internal secretions and the effects which follow any departure from normal in such secretions.

The chemist who will make clear to the medical profession the significance of these obviously vital suggestions is destined to be looked upon by future generations not only as the father of a new school of medicine, but as a benefactor of the human race second only to Pasteur. To date the chemist has not been sufficiently interested in the physician or the physician sufficiently interested in the chemist to bring about between them a keener appreciation of the services that both working together, might render to humanity.

The chemist knows, for instance, that the specific gravity of the blood depends largely upon the base-forming elements of food and that these base-forming elements are to be found chiefly in ripe fruits, grasses, fresh green vegetables and pure milk, whereas animal foods, other than milk, and the seeds of grasses, such as cereals, supply the greater share of the acid-forming elements. It is known that vegetable matter does not decay nearly as readily as animal matter, the putrefaction of which begins shortly after it is acted upon by the digestive ferments.

Vegetables are just as thoroughly digested in the intestinal tract but the extreme decomposition processes which follow digestion are not initiated nearly as quickly in vegetables as in meat. It is known, for instance, that the extreme decomposition of food which makes for putrefaction is responsible for certain types of auto-intoxication. On a diet of bread, vegetables and milk (by bread I mean whole meal bread) these forms of auto-intoxication, unless brought about by some constitutional disorder, are never encountered. One of the most obnoxious products of the putrefaction of proteins is hydrogen sulphide, which has distinct acid properties and which is therefore broken up under the influence of base-forming food. It is not known to what extent hydrogen sulphide in the absence of bases affects the iron content of the blood or other internal secretions. Certain foods like meats are incapable of supplying the bases necessary to neutralize the hydrogen sulphide. Unrefined vegetable foods do supply these neutralizing bases.

When the chemist shows the physician just what happens when the specific gravity of the internal secretions is modified abnormally and just how refined and unrefined foods of vegetable or animal origin bring about this modification, a new era of public health activities will be inaugurated. When the chemist, instead of being engaged in the defence of food abominations with all the odium that attaches itself to these pernicious activities in which eminent college professors have so frequently appeared to the disgrace of their profession, he will be looked upon with a newer and greater honor as the most important of all the influences operating to the development of the healthy normal child and the elimination of the many preventible tragedies of maternity that now contribute so much to the sum-total of human misery.

The Chemist

BY SCHALER SETON

He carries in his hand a shapely glass;
Within, a liquid, colorless and clear,
Reflects the sunlight, but there doth appear
No trace of solute in its limpid mass.
He drops a crystal in. Then comes to pass
A miracle; what once had seemed asleep
Awakes to beauty; lace-like fingers creep
Through the solution, growing like the grass
Till all turns solid. Once in ages dim
God held the world inchoate in His hand.
He dropped a thought in; at the great command
The solid earth first reared to the sun's beams.
So, in his mimic art the chemist dreams
And strives to think God's deep thoughts after Him.

A Twenty Minute Project

By Dwight W. Lott, High School, Lima, Ohio.

We have read many articles in favor of and a few articles against the project method of teaching science. We have heard educational experts deliver addresses which convinced us that the only way an individual, in school or out of school, ever solved a real difficulty was by the project method. So we concluded to use that method in the teaching of science.

But where are we to get our projects? We have seen no printed outlines of projects. We have ventured to ask the educational expert for them, but quite often he replies with much enthusiasm, "My friend, there are hundreds of projects. The world is full of them." Sometimes he states that his field is that of educational philosophy and the bewildered science teacher is left to infer that workable science projects do not grow in that particular field. However, the teacher has received splendid inspiration and many guiding principles from the philosopher.

During the last three years the writer has tried to develop projects for class room use. Ten or twelve hours were often spent in the preparation of a single project. Great care was taken in trying to foresee the psychological time for asking certain questions and for doing certain things. Demonstration experiments were devised and prepared, though not always used, in order to answer experimentally certain questions which the pupils might ask.

As a result of this experience I have not lost faith in the project method. Some success was attained although signs of failure were in evidence quite often.

Several of my "best" projects seemed to be failures. It was like unloading manufactured goods at a station where nobody wanted that brand of merchandise. They wanted "home products." My pet experiments were not called for. If performed at all they were forced on the pupils. The pupils could not sense the problem, did not ask "appropriate" questions, could not organize what material they already had, could not suggest a reasonable hypothesis or could not deductively test the validity of its consequences if they did suggest one; in fact, they were unable or at least unwilling to perform any of the tricks prescribed by our philosopher guides.

Some of my "weakest" projects seemed to be very successful, and some of the most successful ones originated during a class room discussion, were developed and were solved without any outline having been prepared previously by the teacher.

Some of my "best" projects were failures because they were artificial; they had been manufactured to meet a need which was not felt by the majority of the pupils. Logically they were fine; psychologically they were inferior at the time presented. Some of them might have worked well under different conditions but those conditions did not exist at the time of the recitation. Others did work splendidly.

We may safely say that teachers are very rare who can foretell what the composite mood or spirit of a class will be on Thursday of next week or on Monday of the week after next. The same is true with respect to the emotions of the individual pupils. That the emotional element plays a dominant part in the educative process is expressed by Dewey as follows: "Knowledge is impossible without feeling and will."* Also, "Wonder is not only the originator, but it is the continuer of science. Wonder is the emotional outgoing of the mind toward this universe."†

I have come to believe that the most practical projects are among those which arise naturally from the emotions of the pupils. I have not said that every project suggested by a pupil is practical. It is the duty of the teacher to recognize them instantly and select promising ones for solution by the pupils.

So at the beginning of the fourth year's experiment with the project method, we have chosen the motto, "Fewer artificial projects and more natural projects." We have about 325 pupils in general science. They are divided into twelve sections. Each pupil has a text, a splendid book too, yet we have considered the idea of assigning lessons in the text as being artificial. We believe that over half of our pupils study an assigned lesson more because it has been assigned than because they have any natural desire to study. We have now reached the end of the twelfth week and not a single book lesson has been thrust at our pupils. However, at present no claims are made as to the superiority or inferiority of the total educational results of the experiment. We do claim that we have seen more intelligent use made, of textbooks and other sources of

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*Psychology, p. 18.

†Psychology, p. 303.

information, by pupils than we have ever seen before during the same length of time by pupils of the same age. We still prepare artificial projects but use them only when we fail to "stir up" a natural project within five or ten minutes after the recitation begins. Often the next project develops before the present one is finished. The time required for the solution of one project may vary from a few minutes to several days.

Outlines of projects, whether made by others or by ourselves, should be considered as suggestive of what has been done or might be done under certain conditions, but not as detailed specifications of what to do under conditions "subject to change without notice."

The following project is imperfect in several ways, but is an accurate account of what happened in one of my classes this morning. It is given simply as an illustration of what we mean by a natural project.

Sunday was a warm day, Monday was less warm and this morning, Tuesday, the air was quite cold. It was the first period in the morning and the engineer was having difficulty in heating some of the rooms properly. No sooner had the pupils been seated than some of the girls asked permission to get their wraps. I had a certain definite plan in mind for the day's lesson but discarded it at once when it seemed that "the fish might bite better if the bait were changed."

Teacher. "What is the population of Lima?"

Pupil A. "About forty-two thousand."

Teacher. "What did many people talk about this morning?"

Pupil B. "They talked about how cold it is."

Teacher. "About how many Lima people do you think talked about the weather this morning?"

Pupil A. "Twenty thousand."

Pupil B. "I think about twenty-eight thousand."

Pupil C. "No, nearer twenty-five thousand."

Teacher. "Have you any questions to ask this morning?"

Pupil L. "Why does the weather change like it has?"

A pause of two or three minutes.

Pupil M. "I think I know. We get our heat from the sun, and we learned the other day that when the sun's rays hit the ground in a slanting direction, the ground does not get so warm as it does when they strike it in a direction straight down. The change in slant is what causes winter and summer. Winter is coming and the rays slant more every day. They slant more today than they did on Sunday and that's why it is colder today."

The pupils were apparently satisfied for about a minute.

Pupil L. "Yes, but sometimes we have a warm day following a cold day at this time in the fall."

Pupil M. "That's right, my answer will not do."

Teacher. "Do you think any of Walter's statements are correct?"

Pupil K. "Sure, he was right about the sun's rays and they do slant more today than they did Sunday, but there must be some other reason."

Pupil X. "On Sunday we were getting a warm breeze and today we are getting a cold breeze."

Teacher: "Where do you think warm breezes and cold breezes come from?"

Pupil X. "The warm ones come from the south and the cold ones come from the north."

Pupil E. "Why did the wind happen to blow from the south on Sunday and from the north today?"

Pupil A. "The wind always blows from a place where the pressure is high to a place where the pressure is low. Since Sunday, Lima has been in a low pressure area."

Pupil E. "But if we are in a 'low' the air would come from all directions at the same time."

Teacher. "Recall our experiment of pouring water on the large rotating ball." A pause of about two minutes. "What would happen to a wind blowing from the south toward the center of a low pressure area?"

Pupil H. "The rotation of the earth would make the wind blow to some place east of the center."

Pupil D. "Yes, and a wind coming from the north would turn and blow to a place west of the center."

Teacher. "Will the east or west side of a 'low' have the higher temperature?"

Pupil D. "The east side ought to be lots warmer than the west side."

Teacher. "In what direction do 'lows' move in the United States?"

Pupil L. "They move eastward."

Nothing more was said for a little while. Then faces began to beam and hands were raised. One boy was unusually eager to express himself and was given the opportunity.

Pupil L. "When a 'low' moves across this part of the country it is just like a long freight train going at slow speed from the west side of town to the east side. The engine is hot and heats up the town and there is a warm day. The caboose is cold and when it comes along we have a cold spell like today."

Teacher. "Splendid, Harold, but why did you happen to think of a freight train?"

Pupil L. "My dad's an engineer on the Pennsylvania."

Teacher. "This will be all for today."

It was a welcome sight to see more than half of the pupils voluntarily read their general science texts during the remainder of the period?

Does the reader believe in natural projects?

The General Science Situation in Oregon

G. M. RUCH, Senior High School, Ashland, Oregon.

Historical.

The beginnings of general science in Oregon date back to the year 1912-1913, when two high schools, Salem and Union, offered such a course. Both schools later discontinued the work temporarily, although Salem now provides general science in three junior high schools. During the school year 1914-1915, six schools attempted the work and all reported the results as sufficiently satisfactory to warrant the retention of the subject. These schools were McMinnville, Salem, Gold Hill, Bandon, Tillamook and Ashland. In 1915-1916 twenty schools offered general science, a gain of fourteen over the preceding year. The number for this year can only be estimated and the best date obtainable seems to place the total at about thirty-five, a splendid showing for a state with only about 175 high schools.

Methods of Instruction.

In regard to the methods of instruction, it can fairly be said that there is much yet to be desired, but progress is very much in evidence. As with all new subjects, time and experience will solve many problems. The actual working conditions as nearly as can be determined for the state at large are given in summary in the following paragraphs.

All of the schools are using regular text books and about three-fourths are using a laboratory manual as well. No particular text has proved a marked favorite but the Clark and the Caldwell and Eikenberry texts are somewhat in the lead. At least half of the schools use supplementary texts as well.

In the matter of enrollment in general science classes, the total for the entire state for this semester is nearly one thousand pupils. None of the schools segregate the sexes.

The conditions of laboratory instruction are not very satisfactory; but three schools have been able to make the laboratory work entirely individual in character. Six more make half of the laboratory instruction individual but the majority follow the plan of demonstrations by the instructor, together with careful note-book work and a small amount of individual effort. This condition can be credited to large classes and lack of proper laboratory facilities in the smaller schools. Another unfortunate condition is found in that few schools can use the conventional double period for laboratory sections. The prevailing plan is to devote three days a week to recitation and two days to laboratory exercises. Moreover, it is very desirable that each school own a projection lantern for use in general science classes, but thus far only four schools are so equipped.

The most hopeful indication of the future for general science in this state is the working spirit which exists, a spirit of optimism tempered by a desire to subject each rising problem to a careful study. Every teacher of the subject who could be induced to express an opinion has expressed the conviction that the results obtained thus far justify the retention of the subject in our curriculum, and not a single school has yet reported dropping the course because of unsatisfactory results. The number of schools preparing to adopt the new subject within the near future is encouragingly large.